terbury College, University of New Zealand, and to Mr. S. Whiteley of Rhodes University for the Latin descriptions; and finally to Dr. G. F. Papenfuss and Dr. Marion S. Cave for so kindly reading the manuscript, seeing it through the press, and for much helpful advice.

Grahamstown, South Africa

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FLORA OF THE CRESTED BUTTE QUADRANGLE, COLORADO

Jean H. Langenheim

Although the flora of the eastern slope of the Colorado Rockies has been studied in considerable detail, the western slope has received little attention. Several general surveys which include incomplete floral lists have been published, the most complete being Brandegee's (1876), which was intended to be a supplement for southwestern Colorado to Porter and Coulter's "Synopsis of the Flora of Colorado" (1874). Charles F. Baker also published a very incomplete list for the La Plata Mountains in 1898. Names of plants are mentioned in several vegetational surveys of the state (Robbins, 1910; Cary, 1911), and Schmoll (1935) discussed the vegetation of the Chimney Rock Area, Archuleta County. However, there are no truly definitive lists for local areas other than that by Graham (1937) for the Colorado portion of the Uinta Basin.

The following floristic list was prepared in conjunction with a detailed ecological study in the Crested Butte Quadrangle, and represents collections made to document that study. It is prepared for publication previous to the ecological study at the request of several workers who will find it useful to their research in this area. Voucher specimens are in the herbaria at the University of Colorado and the University of Minnesota. Since the rarer species were deemed to be more useful to workers at the University of Colorado, in many instances the only collections of these are at that institution. Large but incomplete collections are in the herbaria at the Colorado A. & M. College, State University of Iowa, and the University of California at Berkeley. I wish to acknowledge the assistance of W. A. Weber, University of Colorado, in verifying or determining the collection in general. The majority of the Compositae, Gramineae, and Cyperaceae were submitted to H. D. Harrington, Colorado A. & M. College. I am also grateful to the following people for assistance in their special groups: C. R. Ball, *Salix;* Lyman Benson, *Ranunculus;* Bernard Boivin, *Thalictrum;* Lincoln Constance, *Umbelliferae* and *Hydrophyllaceae;* G. J. Goodman, *Eriogonum;* F. J. Hermann, *Juncus;* C. L. Hitchcock, *Draba* and *Lathyrus;* D. D. Keck, *Penstemon;* G. B. Ownbey, *Corydalis;* C. L. Porter, *Astragalus* and *Oxytropis;* C. O. Rosendahl, *Saxifragaceae;* E. T. Wherry, *Polemoniaceae;* Robert E. Woodson, *Asclepias.*

The Crested Butte Quadrangle is located in west-central Colorado on the southwest flank of the Elk Range. It is about 35 miles north of Gunnison and 25 miles southwest of Aspen in Gunnison County (fig. 1). The altitude ranges from 8,000 to 13,500 feet. Many types of bedrock occur here although ninety percent is sedimentary rock; the remainder consists primarily of igneous intrusives. The topography is rugged, being in an early mature stage of the erosion cycle modified by glaciation. Climatic conditions are diverse. The only weather station in the area is located at Crested Butte, 8,867 feet, where an average annual rainfall of 28 inches is reported (U. S. Dept. of Commerce, 1952), but weather bureau estimates are as high as 50 inches in portions of the area. There are two maxima of precipitation: from July to September, and during January. The heavy accumulation of winter snow supplies a persistent source of moisture throughout the summer at high elevations. At Crested Butte the mean temperature for July is 56.8° F. and for January, 13.6° F.; the absolute maximum temperature on record is 91° F. and the absolute minimum, — 42° F. (U. S. Dept. of Agric. Yearbook, 1941). Although the temperature extremes at higher elevations are unknown, it is significant that freezing temperatures occur at irregular intervals throughout the growing season.

The vegetation of this area has been disturbed little by the influence of man since the establishment of the Gunnison National Forest in 1909. However, despite a controlled program of grazing which has prevented widespread erosion, the composition of the grassland and meadow com-

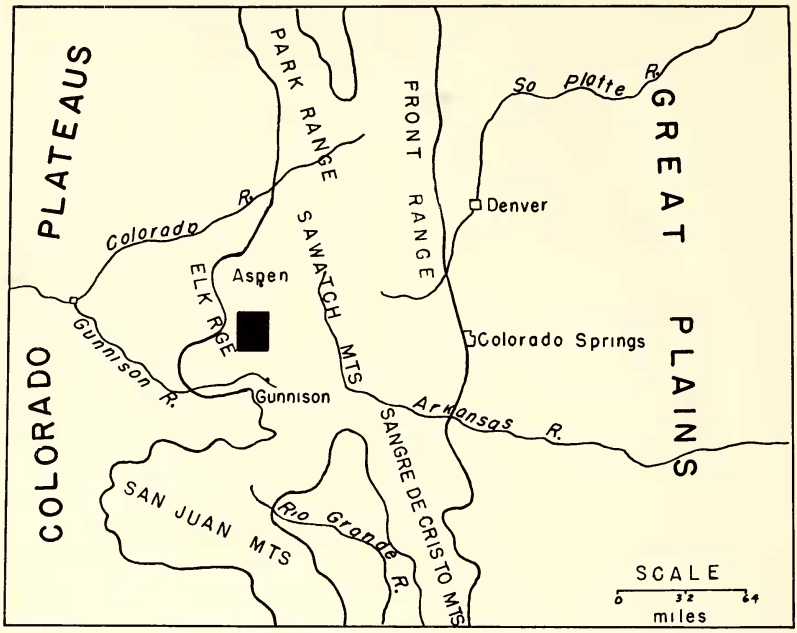

FIG. 1. Index map of Colorado showing location of Crested Butte Quadrangle.

munities has been altered somewhat. A fire history is evident as having occurred between 1880 and 1900, thus coinciding with the peak of mining activity. From this brief discussion, it is evident that the area is one of highly diverse environmental conditions which could be expected to select a rich flora.

The percentages of species representing different floristic elements, as recognized by W. A. Weber (personal communication), are shown in Figure 2. Although the area of the Crested Butte Quadrangle is located on the border of the Colorado Plateau, it is still a part of the Rocky Mountain system. Thus it is not surprising to find that a majority of the species at the elevation of the study area have Rocky Mountain affinities. Further analysis of this Rocky Mountain element shows that the highest percentage of species is either widespread throughout the Rockies or occurs primarily within the Central Rockies; few have Northern Rocky affinities. Species with circumboreal affinities or with distributions widespread over western North America are also common. There is a relatively small representation of species with Great Basin-Colorado Plateau affinities, but observations at lower elevations in the adjacent Gunnison River Valley indicate, as one would expect, a higher representation of species with these relationships.

The flora is organizable into five vegetational zones: sagebrush, aspen, spruce-fir, upland herb, and alpine. The sagebrush zone characterizes the

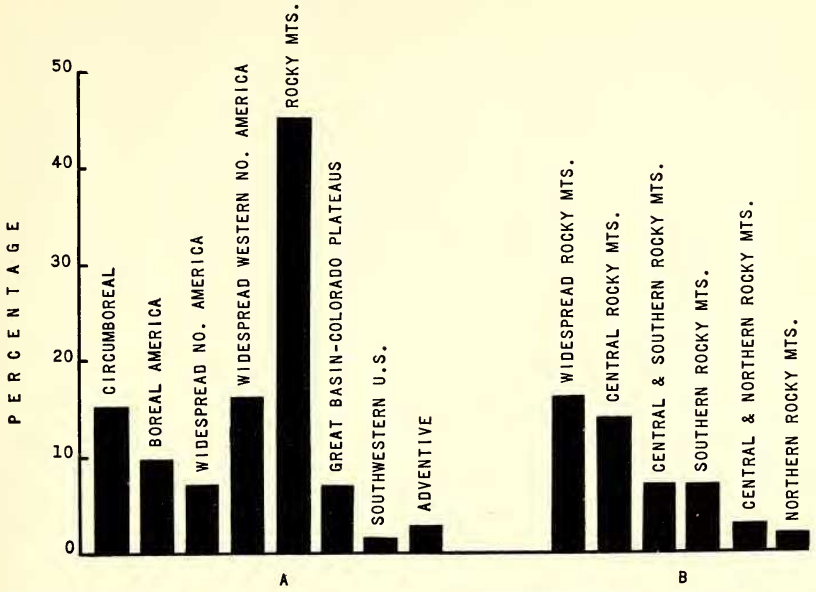

FIG. 2. Floristic relationships of species in the Crested Butte area: A. Percentages of species representing floristic elements recognized by W. A. Weber. B. Analysis of the species in the Rocky Mountain element (see A) into component elements.

8,500-9,500 altitudinal range in the quadrangle and continues downward to approximately 7,500 feet in the adjacent Gunnison River Valley. It seldom occurs above 10,000 feet, but has been observed in patches near timberline. *Artemisia tridentata* is the dominant; other common shrubs are *Chrysothamnus viscidiflorus* and *C. parryi. Festuca thurberi* is the most prominent grass, and characteristic forbs are *Achillea lanulosa, Eriogonum neglectum, Vicia americana, Arenaria congesta, Erigeron speciosus, Lathyrus leucanthus,* and *Potentilla pulcherrima.*

The aspen zone ranges from 8,500 to approximately 11,200 feet. Between 9,500 and 10,500 feet it forms a distinct altitudinal belt, occurring as a continuous open forest below the spruce-fir zone or as groves scattered through the *Festuca thurberi* grassland. *Populus tremuloides* is the dominant. The most common forbs in the mature undergrowth are *Thalictrum fendleri, Ligusticum porteri, Vicia americana,* and *Erigeron elatior. Bromus ciliatus* is the most frequent grass.

The Engelmann spruce-subalpine fir zone is the most extensive one in the Crested Butte area, occurring from 8,500 feet along streamsites to 12,500 feet as patches of *Krummholz.* It is altitudinally well defined, however, only from approximately 10,500 to 11,500 feet. *Picea engelmannii* and *Abies lasiocarpa* are the only tree dominants. A tall shrub layer is composed primarily of *Ribes cereum* and *R. wolfii. Vaccinium myrtillus* and *V. caespitosum* make up a low shrub layer which dominates the forest

floor. *Pedicularis racemosa, Arnica cordifolia, Fragaria ovalis,* and *Polemonium delicatum* are the most frequent herbs. Lodgepole pine, aspen, and *Festuca thurberi* with characteristic associates replace burned spruce-fir forest. Replacement has been most extensive by the grassland in this area.

The upland herb zone is most prevalent from approximately 11,500 to 12,500 feet, but also is characteristic of non-forested areas as low as 10,500 feet. This zone consists of a luxuriant assemblage of grasses, sedges, and showy forbs. The most common forbs are *Senecio crassulus, Ligusticum porteri, Lupinus parviflorus, Delphinium barbeyi, Polygonum bistortoides,* and *Helianthella quinquenervis. Carex ebenea* and *C. chalceolepis* are the most common sedges, with *Phleum alpinum, Poa alpina, P. arctica,* and *Trisetum spicatum* the most important grasses.

The alpine zone is best developed between 12,500 and 13,500 feet, although alpine assemblages interfinger with the upland herb zone as low as 12,000 feet. A well-defined population pattern could not be discerned in this altitudinal range. Characteristic groups of species occur on fell fields, boulder fields, on talus, and along streamsides and snowbanks, but dominance varies widely from stand to stand. Arêtes on which fell fields predominate provide most of the area available to alpine species here. This habitat is relatively barren with only scattered herbaceous growth. *Hymenoxys grandiflora, Artemisia scopulorum, Oxytropis deflexa, Erigeron pinnatisectus, Polemonium viscosum,* and *Silene acaulis* are the most frequent forbs. Patches of sedges with some included grasses occur locally. *Kobresia bellardii, Carex elynoides,* and *C. hepburnii* comprise the prominent sedges. The common grasses are *Poa alpina, Trisetum spicatum, Festuca ovina* var. *brachyphylla,* and *Agropyron trachycaulum.*

An extensive bunch grassland dominated by *Festuca thurberi* occurs within the matrix of all zones from 8,500 to 12,500 feet, being most prevalent on deep soils on south-facing slopes. *Bromus ciliatus* and *Agropyron trachycaulum* are other characteristic grasses. The most frequent forbs are *Achillea lanulosa, Potentilla pulcherrima, Linum lewisii, Erigeron speciosus, Thalictrum fendleri, Lathyrus leucanthus,* and *Vicia americana.*

In considering the floristic relationships of the communities in the area, it was arbitrarily decided to include only those species occurring with a frequency of 50 per cent or more since only these contribute significantly to the definition of homogeneity of the vegetational pattern. The floristic relationships of these species within the vegetational patterns are shown in Figure 3. Species with less frequency contribute only to minor diversities within the patterns.

Boreal, and Central and Northern Rocky Mountain elements are represented in all of the communities, although the latter plays only a minor role in each community. The boreal element occurs most prominently in the aspen community, where it plays the dominant role. Also species with distributions widespread in western North America contribute to all of the vegetational patterns, but they play the dominant role in the sage-

brush, fescue, and spruce-fir communities, being especially noteworthy in the sagebrush community where 63 per cent display this relationship. The Central Rocky Mountain element is represented in all but the fescue and sagebrush communities; it is the most conspicuous element in the upland herb community and takes second place in the alpine zone. The Central and Southern Rocky Mountain element is present in all communities except the alpine, and it places second in the upland herb, fescue, and aspen communities. Species widespread throughout the Rocky Mountains are represented in all but the upland herb community, but assume no outstanding role in any community.

Four other elements are represented only in a limited number of communities. The circumboreal element is restricted to the alpine, upland herb, and aspen communities, but dominates the alpine zone. Species with Great Basin-Colorado Plateau affinities are represented only in the sagebrush and alpine communities which are at elevational extremes. A similar situation in regard to the presence of desert elements in the alpine zone of the Sierra Nevada was noted by Went (1953). Species with Northern Rocky Mountain affinities and those widespread over North America play only insignificant roles in a few communities.

It should be pointed out that, despite the evident relationships of the flora (fig. 2) and the floristic relationships of those species which are at least 50 per cent frequent in the communities (fig. 3), the physiognomic expression of the communities is more similar to that in the adjacent mountainous areas in the Great Basin and Colorado Plateau than to that on the eastern slope of the Rockies. Also the *zonal sequence* appears to be in response to a gradient toward more extreme xeric conditions than in many other localities on the western slope of the Rockies and in adjacent areas in eastern Utah. These conclusions are borne out by the following features. A distinguishable assemblage of grasses and forbs, which occurs in the Crested Butte area between the alpine and spruce-fir zones, has not been recorded on the eastern slope of the Rockies. This upland herb zone does occur, however, in the Uinta Mountains (Graham, 1937) and the Wasatch Mountains (Ellison, 1954). The spruce-fir zone on both the eastern slope and in mountainous areas in the Great Basin usually occupies about a 2,000-foot altitudinal range, but here, except on north exposures, it is restricted to about 1,000 feet, and after fire is replaced more commonly by a grassland than by lodgepole pine or aspen forests. A forest dominated by *Pinus ponderosa* var. *scopulorum* and *Pseudotsuga taxifolia,* which is general on the eastern slope below the spruce-fir zone, is represented in this area only by scattered or isolated trees along canyon walls. This pine-Douglas fir zone is also absent over much of the western slope and adjacent areas in eastern Utah. A zone dominated by *Pinus ponderosa* var. *scopulorum,* but usually without *Pseudotsuga taxifolia* as an associate, does occur, however, in many places in the Great Basin. In place of the pine-Douglas fir zone, below the spruce-fir zone, there usually occurs an altitudinally-defined zone of aspen. Although aspens are abun-

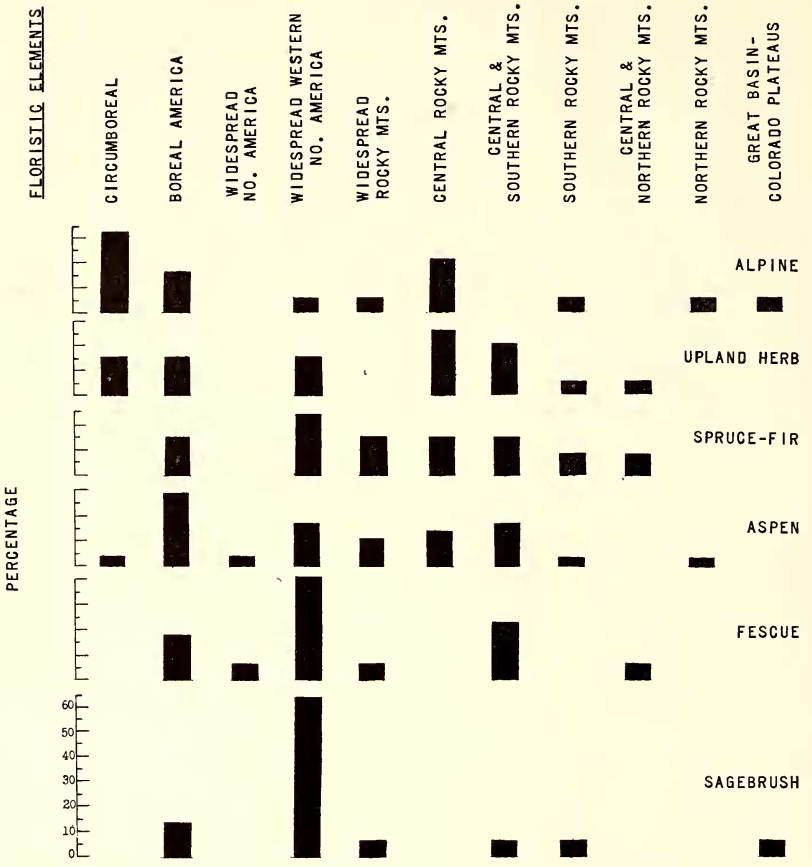

FIG. 3. Floristic relationships of species which are at least 50 per cent frequent within the principal communities in the Crested Butte area.

dant on the eastern slope, they usually do not form a well-defined belt such as has been reported for western Colorado and central Utah (Baker, 1925), the LaSal Mountains (Tanner and Hayward, 1934), the Uinta Mountains (Graham, 1937), the Wasatch Mountains (Lull and Ellison, 1950), and many other areas in the Great Basin. The interzonal grassland community dominated by *Festuca thurberi* also has been reported elsewhere only from the Abajo Mountains (Ellison, unpublished ms.). Generally, over many areas on the western slope of the Rockies and in the Great Basin, the next zone below the aspen belt is one dominated by oaks, followed by one dominated by pinyon and junipers. In the Crested Butte area these zones are absent and in their place is one dominated by *Artemisia tridentata*. Discussions by numerous authors concerning the zonal sequences and the presence or absence of ponderosa pine, oak, pinyon-juniper, and high-altitude sagebrush zones are correlated by Langenheim

(1953). The relatively unique zonal sequence in the area of the Crested Butte Quadrangle may result partially from a steep precipitation gradient between 8,000 and 10,000 feet and partially from the fact that 66 per cent of the area is southwest-facing.

Documentary Collections

Although specimens were collected throughout the area of the quadrangle, intensive collecting was done over the 100 square miles where the vegetation was mapped. Because field investigations of this type are dependent upon sampling procedures, it is improbable that the list is complete. Therefore species (marked with an asterisk) from nearby similar habitats outside the area are included. Eventually it is expected that they will be found within the area of the quadrangle. The list includes 579 species, 245 genera, and 64 families. Numbers following specific epithets are the collection numbers of the author.

Aceraceae

Acer glabrum Torrey, *68, 270*
*A. negundo L., *1430*

Anacardiaceae

*Rhus trilobata Nutt., *1328*

Apocynaceae

Apocynum androsaemifolium L., *500*

Asclepiadaceae

Asclepias hallii Gray, *476, 788*
A. speciosa Torrey, *1376*
*A. subverticillata (Gray) Vail, *1441*

Berberidaceae

Berberis repens Lindl., *184-48, 19*

Betulaceae

Alnus tenuifolia Nutt., *135-48, 1270*
Betula glandulosa Michx., *317-48, 27*
*B. occidentalis Hook., *135-48, 1379*

Boraginaceae

*Cynoglossum officinale L., *1377*
Cryptantha bakeri (Greene) Payson, *1209*
Eritrichium elongatum Wight, *444, 1014, 1274, 2109*
Hackelia floribunda (Lehm.) Johnst., *107, 434, 1420, 3944*
Lappula redowskii (Hornem.) Greene, *114, 1263*
Mertensia ciliata (James) G. Don, *105-48*
M. franciscana Heller, *3957*
M. fusiformis Greene, *10, 11, 1222*
M. viridis Nels. var. cana (Rydb.) Williams, *102-48, 4, 276, 341, 362, 396, 808, 1063, 1113, 1300*
Plagiobothrys scopulorum (Greene) Johnst., *1141*

Callitrichaceae

Callitriche palustris L., *444-48*

Campanulaceae

Campanula parryi Gray, *328, 376, 593, 3866*
C. rotundifolia L., *366, 593, 2145*
C. uniflora L., *439*

Capparidaceae

Cleome serrulata Pursh, *2016*

Caprifoliaceae

Linnaea borealis L., *142, 481, 3914*
Lonicera involucrata Banks ex Sprengel, *182-48, 38*
Sambucus racemosa L., *180-48, 31, 3904*
Symphoricarpos occidentalis Hook., *76*
S. tetonensis A. Nels., *121, 1325*
S. vaccinioides Rydb., *780, 1205, 1314, 1535, 3938*

Caryophyllaceae

Arenaria congesta Nutt., *98-48, 358, 795*
A. macrantha (Rydb.) Nels., *3968*
A. lateriflora L., *126*
A. obtusiloba (Rydb.) Fernald, *427, 2105*
A. sajanensis Willd., *70, 905, 1361, 2106*
A. verna L., *455*
Cerastium arvense L., *1225, 1521*
C. beeringianum Cham. & Schlecht., *560-48, 52, 814*
Lychnis apetala L., *901, 1461*
L. kingii Wats., *433*
Paronychia pulvinata Gray, *1288*
Silene acaulis L., *538-48*
S. menziesii Hook., *174, 822, 882*
S. scouleri Hook., *356, 416, 425*
Sagina saginoides (L.) Karst., *3844*
Stellaria longipes Goldie, *98, 739, 1278*
S. jamesiana Torrey, *1392*
S. umbellata Turcz., *526*

Celastraceae

Pachystima myrsinites Raf., *424-48, 544-48, 24*

CHENOPODIACEAE

Chenopodium album L., *1455*
C. fremontii S. Wats., *323 a*
Monolepis muttalliana (Schult.) Greene, *323 b*

COMPOSITAE

Achillea lanulosa Nutt., *515-48, 1112, 3879*
Agoseris aurantiaca (Hook.) Greene, *22, 161, 972*
A. glauca (Pursh) D. Dietr., *130, 494, 920, 972, 892, 1097, 3936*
Anaphalis margaritacea (L.) Benth. & Hook., *528*
Antennaria anaphaloides Rydb., *325*
A. concinna A. Nels., *350*
A. microphylla Rydb., *829, 1136*
A. parviflora Nutt., *87*
A. rosea Greene, *89-48, 59, 129*
Arnica cordifolia Hook., *46, 64, 90, 371, 1367, 1399, 3908*
A. fulgens Pursh, *493*
A. latifolia Bong., *400 a, 487*
A. mollis Hook., *3963*
A. parryi Gray, *584, 970, 1395, 3907*
A. rydbergii Greene, *1001, 2111*
Artemisia dracunculus L., *531-48, 214, 346, 3929, 3945*
A. frigida Willd., *90, 1531, 3863*
A. ludoviciana Nutt., *371, 825, 841, 3969*
A. scopulorum Gray, *215-48, 820, 1047*
A. spithamaea Pursh, *390*
A. tridentata Nutt., *572, 3864, 3928*
Aster bigelovii Gray, *3868, 3930*
A. coloradensis Gray, *961*
A. engelmannii Gray, *1521, 3903*
A. foliaceus Lindl., *511, 1100, 3869, 3943*
A. foliaceus Lindl. var. frondosus Gray, *1083*
A. glaucodes Blake, *450*
A. leucanthemifolius Greene, *507*
A. porteri Gray, *1261*
Bahia dissecta (Gray) Britton, *466*
Brickellia grandiflora (Hook.) Nutt., *1433*
Chaenactis alpina (Gray) Jones, *331,585, 1504, 3889, 3897, 3954, 3972*
C. douglasii (Hook.) H. & A., *113, 386, 1333*
Chrysopsis hispida (Hook.) DC., *464, 3920*
C. villosa (Pursh) Nutt., *218, 220, 400 a, 570, 1011, 3947*
Chrysothamnus parryi (Gray) Greene, *555, 594, 1121, 1128, 3856*
C. viscidiflorus (Hook.) Nutt., *374, 1122, 1127, 3857*
Cirsium drummondii T. & G. var. acaulescens (Gray) Macbride, *1130*
C. eatonii (Gray) Robins., *3887*
C. parryi (Gray) Petrak, *3885*
C. scopulorum (Greene) Cockl., *921, 1129, 3896, 3962*
Crepis intermedia Gray, *153, 375, 1337*
C. nana Richards, *102, 1427, 1509, 1519, 3922*
Erigeron acris L. var. debilis Gray, *3918*
E. compositus Pursh var. glabratus Macoun, *53*
E. coulteri Porter, *488, 923, 3910, 3917*
E. elatior (Gray) Greene, *378, 1015, 1041*
E. flagellaris Gray, *243*
E. lonchophyllus Hook., *361, 595*
E. melanocephalus A. Nels., *15, 910, 2148*
E. peregrinus (Pursh) Greene, *99, 549, 936, 1023, 2148, 3911*
E. pinnatisectus (Gray) Nels., *26, 104, 359*
E. simplex Greene, *3956*
E. speciosus (Lindl.) DC. var. macranthus (Nutt.) Cronquist, *367-48, 3880*
E. subtrinervis Rydb., *478*
E. superbus Greene, *3919*
E. unalaschkensis (DC.) Vierh., *3967*
E. ursinus D. C. Eaton, *3913*
E. vagus Payson, *283, 432, 988, 1462, 1472, 2055*
Gnaphalium wrightii Gray, *1111*
Haplopappus clementis (Rydb.) Blake, *552*
H. croceus Gray, *1044, 2095*
H. macronema Gray, *903*
H. parryi Gray, *495, 564, 587, 1032, 3895*
H. pygmaeus (T. & G.) Gray, *1503*
H. uniflorus (Hook.) T. & G., *1461, 3960*
Helianthella quinquenervis (Hook.) Gray, *1042, 1415*
Helenium hoopesii Gray, *381, 1419*
Hieracium albiflorum Hook., *2083*
H. gracile Hook., *969*
Hymenoxys acaulis (Pursh) Parker, *1007*
H. grandiflora (T. & G.) Parker, *541-48, 3951*
Lactuca pulchella (Pursh) DC., *3986*
Matricaria matricarioides (Less.) Porter, *3925*
Senecio acutidens Rydb., *109, 151, 388*
S. ambrosioides Rydb., *347, 365, 3862*
S. amplectens Gray, *401, 525, 935, 2153*
S. atratus Gray, *1065, 3865*
S. bigelovii Gray, *924, 1016, 1417*
S. carthamoides Greene, *554, 3921*
S. crassulus Gray, *448, 491, 951*
S. crocatus Rydb., *953*
S. dimorphophyllus Greene, *1095*
S. fendleri Gray, *1384*
S. harbourii Rydb., *963*
S. integerrimus Nutt., *759*
S. porteri Greene, *537, 1520, 3899*
S. pudicus Greene, *1066, 3886*
S. purshianus Nutt., *288*
S. saxosus Klatt., *18, 1258, 1291, 1350, 2089*
S. serra Hook., *503, 504, 1082, 1505, 3948*
S. soldanella Gray, *17, 277, 935, 1458*
S. triangularis Hook., *154*

S. werneriaefolius Gray, *106, 1234, 1248, 2100*
Solidago altissima L., *1431*
S. ciliosa Greene, *1096*
S. decumbens Greene, *1002*
S. glutinosa Nutt., *21, 596*
S. sparsiflora Gray, *321, 449, 1435*
Taraxacum eriophorum Rydb., *420*
T. erythrospermum Andrz., *173*
T. officinale Wiggars., *37, 3941*
Tetradymia canescens DC., *462, 1355, 1412*
Townsendia exscapa (Rich.) Porter, *725, 1227*
T. incana Nutt., *2013, 2020*
T. leptotes (Gray) Osterh., *725, 1292*
T. rothrockii Gray, *52, 422, 772, 1256, 1310*
Tragopogon dubius Scop., *199, 346*
Viguiera multiflora (Nutt.) T. & G., *1456, 3881*
Wyethia arizonica Gray *224-48, 35*

Convolvulaceae

Convolvulus arvensis L., *384*

Cornaceae

Cornus stolonifera Michx., *423-48, 1315, 3974*

Crassulaceae

Sedum integrifolium (Raf.) A. Nels., *45*
S. rhodanthum Gray, *295-48, 556*
S. stenopetalum Pursh, *304-48, 460*

Cruciferae

*Arabis crandallii Robins., *1264*
A. drummondii Gray, *265, 728, 957, 3935*
A. fendleri (Wats.) Greene, *1336*
A. lemmonii Wats., *1116*
Brassica kaber (DC.) L. C. Wheeler, *465*
Capsella bursa-pastoris (L.) Medic., *309, 3933*
Cardamine cordifolia Gray, *29*
Descurainia pinnata (Walt.) Britt., *317*
D. richardsonii (Sweet) O. E. Schulz, *704, 3942*
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REVIEWS

Manual of the Plants of Colorado. By H. D. HARRINGTON. x + 666 pp., Sage Books, Denver. $8.00.

The identification of plants in much of the Rocky Mountain area has been greatly hampered for many years by the lack of up-to-date manuals. The two manuals which have been of most value for Colorado, namely, Coulter and Nelson's "New Manual